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SOME PROBLEMS IN STELLAR PHOTOMETRY

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It is the purpose of this note to point out some of the researches which have been made possible by the development of the selenium and photo-electric photometers. The first advantage of these electrical devices is a considerable increase in accuracy over what is possible by visual and photographic methods. Perhaps the best field for immediate investigation lies in the study of the eclipsing variables, which give us the only direct clue to the actual diameters of stars. Nearly one hundred of these systems are now known, and new ones are continually being found. In the various studies which have been made, there is one line of reasoning which seems to have been overlooked, as follows.

Among the systems discovered, some are constant in light for a large fraction of the period, while others have relatively long times of variation, and are thus easier of discovery and observation. If P be the total period, and D the time of duration of the eclipse, the probability that a star will be faint when observed at any time is D/P. It seems plausible to assume that if we take the number of discovered stars of each class and multiply by P/D we shall get numbers representing the relative occurrence of such objects which are actually visible and might be discovered. For example: suppose that in a random search about the sky we find 5 stars where the eclipse is $\frac{1}{5}$, and 5 where the eclipse is $\frac{1}{10}$ of the period. Then instead of the relative numbers awaiting discovery being equal, it seems much more probable that there are about 25 of the first class to 50 of the second.

There is another consideration that for every double system which exhibits eclipses in our direction, there are others whose orbit planes are inclined so that we miss the eclipse altogether. We may adopt half a stellar magnitude as the ordinary limit above which a star must vary in order to be detected, and if i represents the corresponding inclination the probability of an eclipse of this or greater amount is given by cos i. Conversely, if we have found a certain number of stars with a given type of eclipse, we may multiply by sec i and obtain the corresponding number of such systems with orbit planes in all directions.

Therefore, if we separate the known eclipsing systems into classes according to the ratio P/D and multiply the number in each class by P sec i/D, we get numbers which represent the frequency of occurrence in space of the corresponding systems. From data already brought together by Shapley (*Contributions from the Princeton University Observatory*, No. 3, 82, 1915), the tabulated results have been found. The third line has been derived from the second by the proper multiplication as described, the products being reduced in proportion to make the total of 88.

Value of P/D	2–4	5–7	8–10	11–13	14–16	17–19	20–22
Number of stars observed	12	41	23	7	4	0	1
Relative number existing	3	24	26	16	13	0	6

The interpretation of these results is that there are relatively few systems with components nearly in contact, $P/D = 2$, and there is a distinct preponderance of P/D from 5 to 10, with maximum say at 8. This corresponds to a distance between centers of about 5 times the average radius of the two bodies.

With more data we could derive similar results for each of the spectral classes. The systems with spectra of classes G and K seem to be quite different from the others, and omitting these we find for stars of B, A, and F spectra a close connection between the relative length of eclipses and the average periods.

Value of P/D	2–4	5–7	8–10	11–13	14–20
Number of stars	9	38	22	6	4
Average period, days	1.0	2.4	5.0	11	15

The increase of period with increasing P/D seems to mean, what has been pointed out before, that the stars which are farther apart move more slowly not only on account of the greater distance, but also because these systems are less dense. However, as the density seems to be a marked function of the spectral class, a further discussion with more material is essential.

From these and other simple considerations, we may conclude: *The preponderant type of close binary with components of the same order of size and of equal or unequal brightness, consists of bodies whose distance* *between centers is approximately 5 times their average radius, whose period of revolution is about 4 days, and whose mean density is 1/20 that of the sun. Systems of greater or less separation are not so numerous, or we should find more of them among the eclipsing variables.*

The foregoing discussion is based upon the variables which have been found by visual and photographic methods, but there is abundant field for work in the same lines for the new forms of photometer. Here instead of examining thousands of stars and picking up a variable now and then, it will be better to make a special study of a few stars which from spectroscopic results are known to have large companions. I have made a start in this testing of spectroscopic binaries, and the first two stars observed were found to be variables. Further observations yielded 4 variables out of 11 stars, and among the hundreds of spectroscopic binaries already known, there are no doubt dozens of variables awaiting discovery. The point to emphasize is that not only will systematic studies of stars which vary in light give us direct information, but indirectly we can draw far reaching conclusions about stars which do not vary.

In addition to the eclipses, other causes of light-variation of binaries may be mentioned, such as ellipsoidal figure, orbital eccentricity producing changes in the interaction of radiation of the components, tidal phenomena, and the effects of resisting media. There is a class of objects like *Polaris*, whose spectral variations are accompanied by synchronous light changes, but there is the possibility that these are not double systems. Some day we shall probably be able to assert that all stars with rapid changes in their spectra, whether these be in the shift or the character of the lines, must vary in light, and it will become a practical problem to find really constant stars to be used as standards of comparison. These may be found only by trial, and we shall have to observe stars in groups so as to eliminate the variables. No doubt we shall find a difference in the average amount of variation as we pass along the spectral series.

This takes us to the case of our sun, which, according to Abbot, is a variable star. Of the variation there can not be the slightest doubt, for a single sunspot is enough to change the total light, the only question is how much. In direct measures of the sun's radiation, the chief difficulty lies in the proper allowance for the atmospheric absorption, but this trouble may be eliminated by comparing the reflected light of one of the planets with the light of a number of stars. Probably *Saturn* is a good object for this purpose, as there are few markings on the surface, but *Uranus* would be still better on account of its slower motion, and the greater number of suitable comparison stars which could be found for it.

Another advantage of the selenium and photo-electric methods comes from the fact that the light of a body like a comet, nebula, or star cluster may be compared directly with a point source like a star. In addition to photometric studies of diffuse objects, it is not too much to expect that we shall be able to get a very good measure of the general light of the sky, i.e., measures of the total light of the stars both in and out of the Milky Way.

The photometry of lunar and solar eclipses also presents problems which can be attacked with success. The total light of the corona as well as its distribution will be easy to determine. Measures of the zodiacal light can be made, and also any absorption of star light by these particles near the sun may be detected. This last would require very accurate observations, but would be feasible at a mountain station.

The problems here presented are some of those for which we already have the means of attack, and which will lead to definite results. Besides what may be predicted in a way there is always the probability of something unexpected, and it is evident that only a beginning has been made in the use of the new methods.

THE COMPOSITION OF BRACHIOPOD SHELLS

By F. W. Clarke and W. C. Wheeler

UNITED STATES GEOLOGICAL SURVEY, WASHINGTON

Presented to the Academy, April 8, 1915

The present communication[1] is part of a much larger research relative to the inorganic constituents of marine invertebrates. The object of the investigation is to determine, more definitely than has been done hitherto, just what substances are contributed by each group of organisms to the marine sediments, and therefore to the formation of marine limestones, with especial reference to their magnesian and phosphatic varieties. A few analyses of brachipod shells are already on record; and they show that they fall into two chemically distinct groups—one calcareous, the other highly phosphatic. This conclusion is supported and emphasized by the new data obtained by us, which, however, bring out some minor peculiarities that seem not to have been previously observed. For our material we are indebted to the kindness of Dr. W. H. Dall, who selected typical specimens from among the duplicates in the collection of the U. S. National Museum. First in order come five brachio-